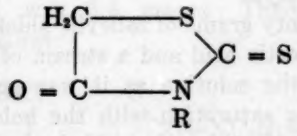
JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

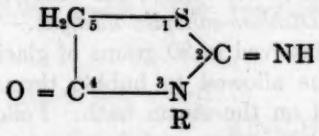
VOL. 16 APRIL 4, 1926 No. 7

CHEMISTRY.—*The condensation of aldehydes with diphenyl isothiohydantoin.* RAYMOND M. HANN and KLARE S. MARKLEY,[1] George Washington University. (Communicated by EDGAR T. WHERRY.)

In continuing the series of researches upon rhodanic acids now being pursued in this University it became a matter of interest to study, comparatively, the reactions of compounds possessing an analogous constitution. Rhodanic acids are the cyclic anhydrides of the dithio-carbamo glycollic acids and may be considered as 2-thio-3-alkyl (or aryl)-4-thiazolidones (I), while the isothiohydantoins are cyclic anhydrides of substituted thiohydantoic acids and may be classed as 2-imino-3-alkyl (or aryl)-4-thiazolidones (II). The close similarity in structure of these compounds has led us to prepare a



(I)



(II)

number of derivatives of 2-phenyl-imino-3-phenyl-4-thiazolidone.[2] Diphenyl isothiohydantoin or 2-imino-phenyl-3-phenyl-4-thiazolidone has been prepared by Lange,[3] and further studied by Lange and Liebermann,[4] who showed that its reduction with alcoholic potassium

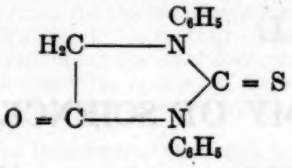
[1] Presented before the meeting of the American Chemical Society, Los Angeles, California, Aug. 3–8, 1925.

[2] Numbering is according to the recommendation of BOGERT and ABRAHAMSON (Journ. Amer. Chem. Soc. **44**: 826. 1922) taking the sulfur atom as 1.

[3] LANGE. Ber. Deutsch. Chem. Ges. **12**: 595. 1879.

[4] LANGE and LIEBERMANN. Ann. Chem. **207**: 123. 1881; see also ANDREASCH. Ber. Deutsch. Chem. Ges. **12**: 1835. 1879.

hydroxide yielded thioglycollic acid and diphenylthiourea. This decomposition and other substantiating facts led them to revise the original structure proposed by Lange (I)



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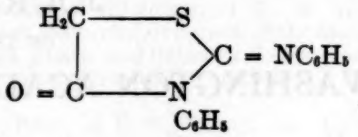


(II)

and substitute the pseudo-thiohydantoin structure (II).

The later structure includes the S-CH_2-CO linkage which has been pointed out by various workers to be a very reactive grouping. Among the compounds which react with the methylene hydrogen in such a combination may be mentioned the aldehydes,[5] isatin,[6] formamidines,[7] alloxan,[8] phthalic anhydride,[9] and phenanthraquinone.[10]

The present paper describes the preparation and properties of a series of aldehyde condensation products of diphenyl isothiohydantoin.

EXPERIMENTAL

Diphenyl isothiohydantoin.[11]—The parent substance was prepared from diphenylthiourea and monochloracetic acid according to the method of Lange.[12] The yield calculated on the basis of diphenylthiourea used, was 60 per cent of theory.

3.5-Dichloro-salicylic aldehyde.—Twenty grams of salicylic aldehyde was dissolved in 80 grams of glacial acetic acid and a stream of dry chlorine allowed to bubble through the solution as it was gently heated on the steam bath. Following saturation with the halogen the solution was cooled and a stream of cold water added to cause precipitation of the substituted compound. After filtering by suction the derivative was recrystallized from dilute alcohol. The yield was 25.3 grams.

[5] WHEELER and JAMIESON. Journ. Amer. Chem. Soc. **25**: 366. 1903.
[6] HILL and HENZE. Ibid. **46**: 2806. 1924.
[7] DAINS and STEPHENSON. Ibid. **38**: 1841. 1916.
[8] BUTSCHER. Monats. für Chemie **32**: 9. 1911.
[9] KUCERA. Ibid. **35**: 137. 1914.
[10] HANN. Unpublished results.
[11] This substance has been prepared by DIXON and TAYLOR (Journ. Chem. Soc. London **101**: 561. 1912) from n-phenyl-*u*-carbethoxy phenylthiourea and chloroacetyl chloride.
[12] LANGE. Ber. Deutsch. Chem. Ges. **12**: 595. 1879.

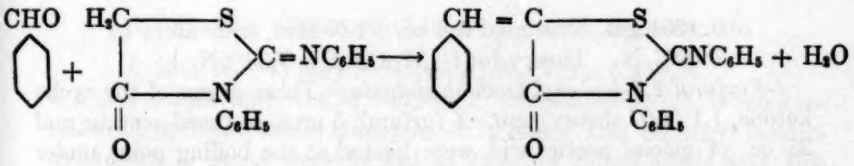
3-Methoxy-4-hydroxy-5-chloro benzaldehyde.—Vanillin was dissolved in glacial acetic acid and a small amount of fused sodium acetate added. Dried chlorine was then lead in, substitution taking place with rise in temperature of the solution and evolution of a slight amount of hydrochloric acid gas. As the reaction continued brilliant colorless crystals separated. Following saturation the crystal meal was filtered off and recrystallized from glacial acetic acid. The chloro-vanillin crystallizes in the tetragonal system and melts at 164–5°C.

3-Methoxy-4-hydroxy-5-nitro benzaldehyde.—Vanillin was nitrated in the cold with fuming nitric acid according to the directions of Bentley.[13] The nitrated compound may be separated from small amounts of side reaction products by recrystallization from alcohol.

3-Methoxy-4-hydroxy-5-bromo benzaldehyde.—Vanillin was brominated according to Dakin's[14] directions, the bromo-aldehyde separating in pure condition from the reaction mixture.

Aldehyde condensation products

5-Benzal-2,3-diphenyl isothiohydantoin.—Dissolved 3 grams of diphenyl isothiohydantoin and 1.2 grams of benzaldehyde in 25 cc. of glacial acetic acid and after adding 5 grams of fused sodium acetate refluxed the mixture for 2½ hours. After cooling an excess of water was added to the reaction mixture, the precipitated condensation product was filtered off, recrystallized from acetic acid and analyzed. The yield was 3.6 grams. Theory 3.98 grams. The reaction was as follows:



5-Benzal-2,3-diphenyl isothiohydantoin is a solid, crystallizing in brilliant platelike crystals of a slight yellow color. It melts at 215–6°C. (cor.).

[13] BENTLEY. Amer. Chem. Journ. **24**: 172. 1900.
[14] DAKIN. Amer. Chem. Journ. **42**: 477. 1909.

Analysis (Boric acid method)[15]

0.2095 gm. consumed 16.3 cc. $\frac{N}{14.01}$ acid, equivalent to 7.78% N. Theory for $C_{22}H_{12}ON_2S$ is 7.86% N.

5-(o-Nitro-benzal)-2,3-diphenyl isothiohydantoin.—The substitution of o-nitro-benzaldehyde for benzaldehyde gave the nitro homologue of the substituted hydantoin. This crystallized in crystalline aggregates of a yellow brown color which gave a yellow powder when crushed. The derivative dissolves in concentrated sulphuric acid with production of a brilliant red color. When heated in a capillary tube it melts at 196–7°C. (cor.).

Analysis (Salicyl-Sulfonic acid method)

0.1128 gm. consumed 8.7 cc. 0.1 N acid, equivalent to 10.80% N. Theory for $C_{22}H_{16}O_3N_2S$ is 10.47% N.

5-Cinnamal-2,3-diphenyl isothiohydantoin.—This derivative was prepared exactly as that preceding, using 1.5 gms. (theory 1.48 gms.) of cinnamic aldehyde and 3 gms. of thiazolidone. The compound separated from the boiling reaction mixture. It was filtered off from the hot solution, washed with hot glacial acetic acid and dried. The yield was quantitative. This condensation product separates in brilliant yellow needles, which are slightly soluble in hot glacial acetic acid and almost insoluble in other organic solvents. It melts at 225–6°C. (cor.) to a clear red oil.

Analysis (Kjeldahl-Gunning-Arnold method)

0.1264 gm. consumed 6.4 cc. 0.1 N acid, equivalent to 7.09% N. Theory for $C_{24}H_{18}ON_2S$ is 7.33%N.

5-Furfural-2,3-diphenyl isothiohydantoin.—Three grams of the cyclic ketone, 1.1 (1.07 theory) gm. of furfural, 5 gms. of fused acetate and 25 cc. of glacial acetic acid were heated at the boiling point under reflux condenser for 2 hours. To the cold solution an excess of water was added when the furfurilidene derivative separated in brown needles. These were filtered by suction, washed repeatedly with water and recrystallized from acetic acid. Heated in a capillary tube they melted at 221–2°C. (cor.) to a black tar-like mass.

[15] MARKLEY and HANN. Journ. Assoc. Off. Agric. Chem. 8: 455. 1925.

Analysis (Boric acid method)

0.2050 gm. consumed 16.65 cc. $\frac{N}{14.01}$ acid, equivalent to

8.12% N. Theory for $C_{20}H_{14}O_2N_2S$ is 8.09% N.

5-Salicylal-2,3-diphenyl isothiohydantoin.—Three grams of thiohydantoin and an excess of salicylic aldehyde (theory 1.36 gms.) were heated with 5 gms. of fused sodium acetate and 25 cc. of glacial acetic acid. After 20 minutes an orange crystalline compound separated out, but the heating was prolonged for two hours to insure complete reaction. After cooling the mass was treated with water, filtered, dried and recrystallized from acetic acid. It separates in yellow acicular needles which dissolve in concentrated H_2SO_4 to give a deep red color. Heated in a capillary tube it melts at 249–50°C. (cor.) to a clear red oil.

Analysis (Boric acid method)

0.2006 gms. consumed 15.1 cc. $\frac{N}{14.01}$ acid, equivalent to

7.53% N. Theory for $C_{22}H_{16}O_2N_2S$ is 7.53% N.

5-(3, 5-Dichloro-salicylal)-2, 3-diphenyl isothiohydantoin.—This compound results as a product of the condensation of 2.5 (2.13 theory) gms. of chlorinated aldehyde and 3 gms. of the cyclic thiazolidone. After purification by several recrystallizations from acetic acid it separated in yellow needles which melted at 234–5°C. (cor.).

Analysis (Boric acid method)

0.2006 gms. consumed 12.6 cc. $\frac{N}{14.01}$ acid, equivalent to

6.28% N. Theory for $C_{22}H_{14}O_2N_2Cl_2S$ is 6.35%N.

5-(3,4-Dihydroxy-benzal)-2,3-diphenyl isothiohydantoin.—When a solution of protocatechuic aldehyde (1.72 gms.) and diphenyl isothiohydantoin (3 gms.) were heated in 25 cc. of glacial acetic acid, this product precipitated after one hour. It was filtered off by suction, washed with hot acetic acid and upon drying was obtained as a brilliant microcrystalline powder of light brown color. It does not melt below 300°C.

Analysis (Kjeldahl-Gunning-Arnold method)

0.1458 gms. consumed 7.0 cc. 0.1 N acid, equivalent to
6.73% N. Theory for $C_{22}H_{17}O_2N_2S$ is 7.22% N.

5-(3-Methoxy-4-hydroxy-benzal)-2,3-diphenyl isothiohydantoin.—If an excess of vanillin be heated in the presence of a dehydrating agent with diphenyl isothiohydantoin, the elements of water are eliminated and the vanillal compound is obtained. This crystallizes in yellow shining leaflets which melt at 250–1°C. (cor.) to a clear yellow oil.

Analysis (Kjeldahl-Gunning-Arnold method)

0.1205 gms. consumed 5.7 cc. 0.1 N acid, equivalent to 6.63% N. Theory for $C_{23}H_{19}O_3N_2S$ is 6.97% N.

5-(5-Chloro-vanillal)-2, 3-diphenyl isothiohydantoin.—Chloro-vanillin (2.1 gms.) and diphenyl isothiohydantoin (3 gms.) were heated in the presence of acetic acid and sodium acetate for a period of 8 hours. After standing overnight the solid which separated was filtered off and recrystallized from acetic acid. It separates in fluffy crystalline masses of yellow needles which melt with decomposition at 132–4°C. (cor.).

Analysis (Kjeldahl-Gunning-Arnold method)

0.1115 gms. consumed 4.8 cc. 0.1 N acid, equivalent to 6.03% N. Theory for $C_{23}H_{18}O_3N_2SCl$ is 6.41% N.

5-(5-Nitro-vanillal)-2,3-diphenyl isothiohydantoin.—This compound was precipitated as a yellow microcrystalline powder by addition of water to a heated reaction mixture containing its constituents in molecular proportion. It melts slowly and with decomposition at 100–2°C.

Analysis (Salicyl-sulphonic acid method)

0.1155 gms. consumed 7.5 cc. 0.1 N acid, equivalent to 9.10% N. Theory for $C_{23}H_{18}O_5N_3S$ is 9.40% N.

5-(5-Bromo-vanillal)-2,3-diphenyl isothiohydantoin.—The brominated 3-methoxy-4-hydroxy benzal condensation product was prepared by the general method, given above. It separates from acetic acid as a yellow brown powder which fails to melt sharply, some decomposition beginning at 100°C. and incipient formation of a black tar results as the temperature is raised.

Analysis (Kjeldahl-Gunning-Arnold method)

0.1186 gms. consumed 5.0 cc. 0.1 N acid, equivalent to 5.91% N. Theory for $C_{23}H_{18}O_3NSBr$ is 5.82% N.

SUMMARY

Diphenyl isothiohydantoin has been condensed with benzaldehyde, o-nitro-benzaldehyde, cinnamic aldehyde, furfural, salicylic aldehyde, 3,5 dichloro salicylic aldehyde, protocatechuic aldehyde, vanillin, chloro-vanillin, nitro-vanillin and bromo-vanillin, and the condensation products analyzed and described.

GEOLOGY.—*Note on the occurrence of the Choptank formation in the Nomini Cliffs, Va.*[1] WENDELL C. MANSFIELD, U. S. Geological Survey. (Communicated by L. W. STEPHENSON.)

The Choptank formation, the middle formation of the Chesapeake group of the Maryland Miocene, was recognized in the Nomini Cliffs, Westmoreland County, Va., by Shattuck[2] in 1904. He says: "In the Nomini Cliffs, Virginia, it [the Choptank formation] is present as a 50-foot bed between the Calvert formation below and the St. Mary's formation above."

In 1906 Clark and Miller,[3] discussing the occurrence of the Choptank in Virginia, stated: "This formation is prominently exposed in southern Maryland and Virginia, outcropping in a nearly complete section in the Nomini Bluffs on the Potomac River."

In the same year Shattuck and Miller[4] reiterated the earlier statement of Shattuck as to the occurrence of the Choptank in the Nomini Cliffs.

In 1912, however, Clark and Miller[5] referred the entire Miocene portion of the section at Nomini Cliffs to the Calvert formation, recognizing neither the Choptank nor the St. Marys formation in that exposure. They wrote:

> "The deposits hitherto described as Choptank in the Nomini Bluffs are now known, from a more exhaustive study of both the stratigraphy and paleontology, to belong to the Calvert formation. It is possible that the Choptank may be represented, as it gradually thins out, in the low country lying between the known outcrops of the Calvert and St. Mary's formations but buried beneath the cover of Pleistocene formations."

The purpose of this note is to confirm the presence of the Choptank formation in the section at Nomini Cliffs, as originally interpreted

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] SHATTUCK, G. B., Md. Geol. Survey, Miocene Text, pp. LXXIX–LXXX, 1904.

[3] CLARK, WM. B., and MILLER, B. L., Va. Geol. Survey Bull. **2**: 18, 1906.

[4] SHATTUCK, G. B., and MILLER, B. L., U. S. Geol. Survey Geol. Atlas, St. Marys folio (No. 136), Md.-Va., p. 3, col. 2, 1906.

[5] CLARK, WM. B., and MILLER, B. L., Va. Geol. Survey Bull. **4**: 140–141, 1912.

by Shattuck, and also to indicate the occurrence of the basal portion of the overlying St. Marys formation.

The Choptank formation in Maryland, according to Maryland Geological Survey Text, 1904,[6] is subdivided into five zones, which are numbered 16 to 20, inclusive. Zones 17 and 19 are very fossiliferous, corresponding respectively to "zone e" and "zone f" of Harris,[7] while zones 16, 18 and 20 are either without fossils or sparingly fossiliferous.

A comparison of the stratigraphic sequence, lithologic character, and faunal contents of the beds exposed in the Calvert Cliffs, Maryland, with those in the Nomini Cliffs and elsewhere in Virginia, seems to show conclusively that the Choptank formation is represented in the Nomini Cliffs. One section in the Calvert Cliffs very closely duplicates the section in one part of the Nomini Cliffs. The Maryland and Virginia sections are given below.

Section about 1½ miles below Flag Pond, Calvert Cliffs, Calvert County, Maryland

By W. C. MANSFIELD and W. P. POPENOE

	Approximate thickness
	Feet
Pleistocene:	
Sand and gravel	30–40
Miocene:	
St. Marys formation:	
Drab plastic clay (zone 22)	15
Clean fine-grained sand, 3 feet, underlain by dark gray slightly sandy semi-plastic clay, with a few fossil impressions (zone 21)	18
Choptank formation:	
Bluish sandy clay, with a 1-foot layer of indurated fossiliferous sand at top containing the following species: *Pedalion maxillata* (Deshayes), *Pecten madisonius* Say, *Asaphis centenaria* (Conrad), *Metis biplicata* Conrad, *Discinisca lugubris* (Conrad), *Schizoporella doverensis* Ulrich and Bassler[8] (zone 20)	20
Light brown very fossiliferous sand with an indurated sandstone layer, about 2 feet thick, at the top, carrying many individuals of *Pecten madisonius* Say (zone 19)	10–12
Bluish poorly fossiliferous sandy clay (zone 18)	8–10
Dark gray very fossiliferous sand (zone 17), exposed	1

The subdivisions in the preceding section are separated into zones believed to correspond approximately to those designated in the Maryland Geological Survey Miocene Text, 1904.

[6] *Op. cit.*, pp. LXXXI–LXXXII.

[7] HARRIS, G. D., Amer. Journ. Sci. **45**: ser. III, pp. 21–31, 1893.

[8] Identified by Dr. RAY S. BASSLER, of the U. S. National Museum.

Section of Nomini Cliffs, right bank of Potomac River, Va., about 1½ miles from lower end of Cliffs

By W. C. MANSFIELD

	Approximate thickness
	Feet
Pleistocene:	
Reddish clay, sand and gravel	40
Miocene:	
St. Marys formation:	
Very plastic unfossiliferous sandy clay. Upper 3 feet consists of laminated clay alternating with thin fine sand partings. (Corresponds to zone 21.)	18
Probably Choptank formation:	
Material similar to the above but contains 2 or 3 ferruginous layers. Appears to be unfossiliferous. (Corresponds approximately to zone 20.)	30
Choptank formation:	
Dark brown rather soft fossiliferous sand, with an indurated sandstone layer about 2 feet thick at the top containing many individuals of *Pecten madisonius* Say. The following species were obtained from the sands: *Arca staminea* Say, *Pecten madisonius* Say, *Pecten marylandicus* Wagner, *Astarte obruta* Conrad, *Dosinia* sp. (Corresponds to zone 19.)	10
Probably Choptank formation:	
Fossiliferous greenish-gray clayey sand. One large specimen of *Isocardia fraterna* Say was found 20 feet below indurated sandstone ledge. (Believed to correspond to zone 18 and perhaps to zone 17.)	30

In the above section no fossils were found above the indurated layer that overlies zone 19. In places, where the material has not slumped, the cliffs stand nearly vertical and are impossible to scale, and the exact thickness of the Choptank formation can not readily be determined, but it probably amounts to 50 feet or more. The recognition of the Choptank formation in the section is based chiefly on the fossils contained in the dark brown sand 30 to 40 feet above the base. The following species, as listed above, indicate the correspondence of this layer with zone 19 of the Maryland Choptank: *Arca staminea* Say[9] is reported only from the Choptank formation; *Pecten Marylandicus* Wagner[10] is reported at six localities in the Choptank formation and at only one in the Calvert formation; *Astarte obruta* Conrad[11] is reported only from zone 19 of the Choptank formation at Governor Run.

[9] Md. Geol. Survey, Miocene Text, p. 388, 1904.
[10] *Op. cit.*, p. 377.
[11] *Op. cit.*, p. 354.

MINERALOGY.—*A petrographic and X-ray study of the thermal dissociation of dumortierite.* N. L. BOWEN and R. W. G. WYCKOFF. Geophysical Laboratory, Carnegie Institution of Washington.

INTRODUCTION

Dumortierite is an aluminous mineral to which the formula $4Al_2O_3 \cdot 3SiO_2$ was originally assigned but which is now known to contain boron as an essential constituent. Several studies of the boron content, especially by Whitfield, by Ford, and by Schaller, have led to somewhat inconclusive results as to whether it is a fixed quantity, but Schaller's conclusion that dumortierite is represented by the definite formula $8Al_2O_3 \cdot 6SiO_2 \cdot B_2O_3 \cdot H_2O$ appears to be in accord with most reliable analyses.[1] A recent analysis, however, gives results closer to the formula $8Al_2O_3 \cdot 7SiO_2 \cdot B_2O_3 \cdot H_2O$ so that the question of variability in composition must be left more or less open.[2] Nevertheless, no reliable determinations indicate any important departure from the formula suggested by Schaller. There is present ordinarily a moderate amount of iron and titanium whose oxides presumably replace alumina and impart the commonly observed colors.

On account of its high Al_2O_3 content dumortierite has been considered as a possible basis of refractory wares. Its behavior at high temperatures is of some interest in the light of the revised Al_2O_3-SiO_2 diagram which shows that the stable compound of these oxides at high temperatures is mullite, $3Al_2O_3 \cdot 2SiO_2$. A paper setting forth the results of an examination of the mineral is therefore an appropriate addition to the series of papers from this Laboratory on alumina-silica and aluminum silicate minerals.[3]

In the present study attention was directed principally to the dumortierite from Clip, Arizona, because its chemical composition is known and the actual analyzed sample, U. S. National Museum No. 48,200, was available for study. The analysis of this material as given by Whitfield is stated in Table 1 under A[4] and with it, under B, a later analysis by Ford of dumortierite from the same locality.[5] The agreement is seen to be reasonably good. Titanium is undoubtedly present

[1] W. T. SCHALLER. Amer. Journ. Sci. (4) **19**: 211. 1905.

[2] T. L. WALKER. University of Toronto Studies, Geol. Series No. 14, p. 80. 1922.

[3] BOWEN and GREIG. Journ. Amer. Ceram. Soc. **7**: 238–254. 1924.
BOWEN, GREIG and ZIES. This JOURNAL **14**: 183–191. 1924.
GREIG. Journ. Amer. Ceram. Soc. **8**: 465–484. 1925; and Amer. Journ. Sci. **11**: 1–26. 1926.

[4] Amer. Journ. Sci. **37**: 218. 1889.

[5] Amer. Journ. Sci. **14**: 428. 1902.

in this mineral in considerable quantity but no determination of the amount has been made.

In addition to the more detailed thermal examination made of this Arizona material occasional comparative tests of other dumortierites were made as noted below.

THERMAL STUDY

The Clip mineral is of a deep blue color. This color disappears in a few seconds if the mineral is heated at about 800°C., at least in an oxidizing atmosphere, and the mineral becomes pure white. After $4\frac{1}{2}$ hours at 800°C. the powdered mineral shows no trace of sintering. Under the microscope there is a suggestion of turbidity indicating that some decomposition may have begun, but there is no change of refractive indices or definite measurable change of any kind.

TABLE 1.—COMPOSITION OF DUMORTIERITE FROM CLIP, ARIZONA

	A	B
SiO_2	27.99	29.86
Al_2O_3	64.49	63.56
Fe_2O_3		0.23
B_2O_3	4.95	5.26
H_2O	1.72	1.41

After four hours at 950° the fine powder again shows no sintering. A definite change is now to be made out under the microscope. Irregular dark streaks have developed with elongation transverse to the prism, giving a fibrous appearance, but each grain as a whole is still of uniform extinction and negative elongation similar to the original grain of dumortierite. The refractive indices are, however, definitely lowered, γ now being 1.68, whereas it was originally 1.69.

When held at 1200° for only 10 minutes the dumortierite is almost completely changed to a material of very much lower refractive index than dumortierite. Each grain still contains, however, rare rests of unchanged dumortierite of random distribution but of uniform orientation. After 30 minutes at this temperature the mineral is completely transformed into the same substance of low refraction. This is made up of fanlike groups of radiating, fibrous structure, the fibers having fairly strong double refraction and positive elongation. It has all the appearance, even under the highest powers of the microscope, of a crystalline aggregate made up of a single substance with a mean refractive index of 1.61. When heated for longer periods the only

further change is the increasing development of irregular dark streaks that are probably cracks or voids which do not extend to the exterior of the grain and therefore do not become filled with the immersion liquid. The fibrous aggregate itself does not change appreciably in properties and is still of mean index 1.61 after heating for some days at 1200°, although the mineral continually loses weight during this period.[6]

X-ray examination (powder method) of the decomposition product of dumortierite as obtained at 1200° shows all the characteristic lines of mullite strongly developed and mullite is unquestionably the principal constituent.

Greig has shown that the mixture of mullite and silica obtained by heating cyanite has a mean index of 1.625, a value which is satisfactorily accounted for by the relative proportions of silica and mullite in the aggregate.[7] The very low index (1.61) of the material obtained by heating dumortierite at 1200° can not be similarly explained, for after long heating, when most of the B_2O_3 is expelled, the material should contain only a very small amount of silica in addition to the mullite revealed by the X-rays as the dominant constituent. The mean index should therefore be only slightly lower than that of mullite. It would appear to be necessary to imagine the presence of submicroscopic voids in order to account for the low index.

Results of an intermediate character are obtained at temperatures between 950°C. where the first suggestion of a change is observed, and 1200°C., where complete transformation to material of low index (1.61) is readily effected. At 1100° the product is not significantly different from that obtained at 950°. At 1150° after 4 hours a small proportion of the dumortierite is transformed into the material of low refringence, and at 1180° after 4 hours a large proportion has suffered a like change. The X-ray diffraction patterns of these intermediate products show increasing development of the mullite lines and decreasing effects from dumortierite (Fig. 3).

After two hours at 1400°C. there is again no appreciable sintering of the powder. Under the microscope each grain is now seen to be completely decomposed and to show with moderate magnification as a nearly opaque, turbid aggregate. With high powers, two substances are definitely to be made out and, while the material is too fine-grained to permit accurate determinations, the one appears to have

[6] See loss of B_2O_3 on heating as given on a later page.

[7] J. W. GREIG. Amer. Journ. Sci. 11: 5–6. 1926.

the refractive indices of mullite, $3Al_2O_3 \cdot 2SiO_2$; the other, which occurs in very small amount, is of very low index and must consist essentially of silica and boric oxide. There is no definite relation between the elongation of the fibers of mullite and the crystallographic directions of the original dumortierite, nor is there more than a moderate tendency for the mullite fibers to grow normal to the surfaces of the original dumortierite grains. In these respects the decomposition of dumortierite differs from that of andalusite on the one hand and cyanite on the other.[8] The actual arrangement of the mullite fibers in the aggregates formed from dumortierite seems to be entirely random. Each grain of dumortierite gives a number of interfering fan-shaped aggregates of mullite fibers. Continuation of the heating for 6 hours at this same temperature (1400°) does not afford any appreciable further growth of the mullite fibers. It is to be noted that both products of decomposition are less dense than the original dumortierite, so that the change must involve some increase of volume.

After 4.5 hours at 1500° the powder is very weakly sintered into a mass which readily breaks down again into a powder between the fingers. The microscope shows the same type of decomposition as that obtained at 1400°. The mullite fibers are not significantly coarser. One observes under the microscope merely that the main bulk of the substance is a birefracting aggregate which matches a liquid of the mean index of mullite and that in it are embedded minute dots of a substance of very much lower index which can be only silica.[9] By way of confirmation of the microscopic determination of the principal substance as mullite an X-ray photograph of the powder has been made and it shows all the characteristic lines of mullite well developed. No lines indicating any form of silica were noted, but since the silica is present in such very small amount this fact is not surprising. The lines of mullite are not distinguishable from those of sillimanite with certainty, but sillimanite is definitely ruled out in the present case because the excess material would then be corundum, and the very low index of the excess material proves that it is not. The formation of mullite and silica is in fact in complete accord with all our past observations on the behavior of synthetic mixtures or natural minerals more siliceous than $3Al_2O_3 \cdot 2SiO_2$.[10]

[8] J. W. GREIG. Amer. Journ. Sci. **11**: 3–12. 1926.

[9] As shown on a later page, B_2O_3 is now completely expelled.

[10] VERNADSKY heated dumortierite from this same locality to a "dazzling white heat" and concluded that the product was sillimanite. (Bull. Soc. Min. Fr. **13**: 258. 1890.) The above observations show that the product was necessarily mullite with a very little silica.

After ¾ hour at 1550° there is decided sintering to a firm cake and the color is now no longer a pure white, as it is after heating at lower temperatures, but is a pale grayish buff. Under the microscope it is found that definite prisms of mullite have developed, with an interstitial material of low index which is undoubtedly glass. Definite formation of some liquid is indicated by both the macroscopic and microscopic characters, the structure of this mass being altogether different from that of the individual grains as decomposed in the solid state at lower temperatures.

The behavior of dumortierite on heating is thus seen to be for all practical purposes that of material containing only alumina and silica.

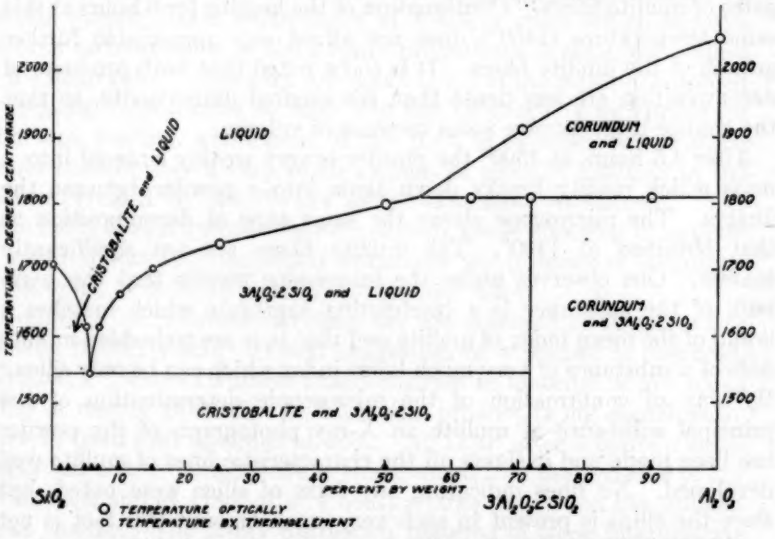


Fig. 1.—Equilibrium diagram of the system: Al_2O_3-SiO_2 after Bowen and Greig

The equilibrium diagram of these oxides, Fig. 1, shows that beginning of melting occurs at 1545° in all mixtures lying between $3Al_2O_3 \cdot 2SiO_2$ and SiO_2 and in dumortierite no melting is observed until that temperature is reached. The B_2O_3 is either lost at these temperatures or the retained portion of it exerts a negligible influence.

LOSS OF B_2O_3 ON HEATING

In order to determine the readiness with which boric oxide (and water) can be driven off from dumortierite on heating, weighed samples were heated at various temperatures and the loss of weight determined.

It is to be borne in mind that the losses here given are those sustained by pure dumortierite and nothing is implied regarding the rate of loss from impure mixtures containing bases that may form more stable compounds with B_2O_3. As might be expected, the rate of loss increases with increasing temperature, the actual results obtained being given in Table 2.

TABLE 2.—Loss of Weight of Dumortierite on Heating

NUMBER	TEMPERATURE	TIME	LOSS OF WEIGHT
	°C.	hrs.	per cent
1	950	4	1.76
2	1200	1	2.18
3	1200	19	3.48
4	1200	46	4.10
5	1200	86	5.02
7	1400	1	2.95
8	1500	2.5	5.9
9	1500	4.5	6.6

Note: The product of No. 5 was returned to the furnace at 1250° and found to suffer an additional loss of 1.42 per cent in 44 hrs. Thus in 130 hrs. of heating, 86 of which were carried out at 1200° and 44 at 1250°, the total loss was 6.44 per cent.

The dumortierite contains about 6.7 per cent $H_2O + B_2O_3$ (see analyses of Table 1) and by reference to Table 2 it will be seen that these are quantitatively expelled at 1500°C. in 4.5 hours, whereas at 1200°C. it requires more than 130 hours to accomplish this result. At temperatures above 1500°C. B_2O_3 is, no doubt, given off still more rapidly. It is not surprising, therefore, that dumortierite should behave at high temperatures as an alumina-silica mixture. One might expect some melting at temperatures below 1545°, the eutectic between silica and mullite, on account of the retention of some B_2O_3 for a considerable period at those temperatures, but apparently its effect is negligible, for no evidence of melting is observed until after a temperature of 1545° is passed.

X-ray observations

Powder diffraction photographs have been prepared and analyzed from Arizona dumortierite and from samples of this mineral heated at various temperatures.

Accurate spacing measurements upon its principal powder lines were obtained from a series of comparison photographs from samples of dumortierite mixed with NaCl to serve as a standard. The spacings

thus determined were employed in standardizing a series of films of dumortierite alone. From these last photographs the spacings of additional lines could be found. Results of these calculations are contained in Table 3. The pattern of dumortierite contains many faint lines. On account of this multiplicity of lines many of them are not clearly resolved in the present photographs and several of the

TABLE 3.—Powder Photographic Data on Dumortierite

SPACING	INTENSITY
5.996Å	m
5.116	f
4.306	f
3.88	ff
3.483	m
3.258	f
2.92	m
2.69	ff
2.17	f
2.089	m
2.01	ff
1.925	ff
1.656	f
1.617	ff
1.546	f
1.460	m (d)
1.330	m
1.291	f
1.175	f (d)
1.063	ff
1.040	ff
0.973	f
0.934	ff
0.914	ff
0.877	f
0.846	ff
0.820	f

Note: Lines marked (d) in this table are diffuse. Probably they are unresolved pairs of reflections. In this and in Table 4 s, m, f and ff stand for strong, medium, faint and very faint.

spacings of Table 3 undoubtedly refer to such composite reflections. This table, furthermore, is not complete because in several instances clearly visible groups of partially resolved reflections give effects so diffuse that no precise significance can be attached to measurements upon them. For the present essentially analytical uses of these patterns, however, such incomplete data are entirely adequate.

Writing the formula of dumortierite as $8Al_2O_3 \cdot B_2O_3 \cdot 6SiO_2 \cdot H_2O$,

this mineral might conceivably be considered as a hydrated mullite, $3Al_2O_3 \cdot 2SiO_2$, in which some of the alumina is replaced by boric oxide. In view of this possibility it is of interest to contrast the powder patterns of these two compounds. Tracings of their photographs are shown in Figure 2. They clearly have no obvious relation to one another.

Powder photographs have also been studied from samples of dumortierite heated for 4 hours at various temperatures. Spacing measurements upon them are stated in Table 4, their tracings are to be found in Figure 3. The principal lines of these photographs are seen to be essentially identical with the principal lines in the patterns of either

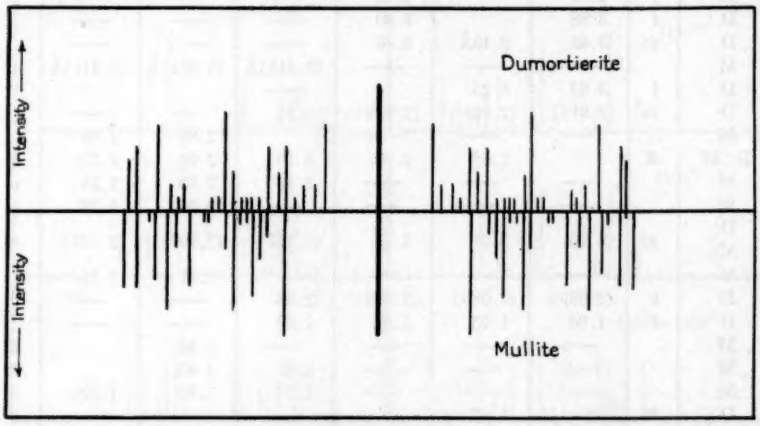


Fig. 2.—Tracings of the positions of the principal powder lines of dumortierite and of mullite. The lengths of the lines in this diagram are roughly proportional to the relative intensities of the corresponding reflections.

dumortierite or mullite. The measurements upon these photographs are not absolute determinations of spacings but were obtained by taking three or four conspicuous lines on each film as standard and establishing the relation of other lines to them. Such a simple procedure is sufficient for the present purposes.

Since dumortierite loses boric oxide and water at temperatures far below those at which the mullite pattern is observed it might be expected either that the dumortierite pattern itself would change as a result of these heatings, or that an amorphous material would appear as an intermediate stage in the decomposition of dumortierite. Small differences in relative intensities between the patterns of natural dumortierite and of this mineral after heating to 1100° and 1150°

appear to exist but the data of Table 4 show no well-defined alterations in the observed spacings. These diffraction observations thus prove that the structure of dumortierite remains essentially unchanged after heating for 4 hours at 950° and 1100°C. and that mullite is the chief product arising from heating dumortierite to 1200° or 1500°C.

TABLE 4.—SPACING DATA ON DUMORTIERITE DECOMPOSED AT VARIOUS TEMPERATURES

ORIGIN OF LINE		SPACINGS AND APPROXIMATE INTENSITIES						
		950°	1100°	1150°	1180°	1200°	1500°	
D	m	5.91Å		5.82Å	—	—	—	
D	f	5.11		5.00	—	—	—	
D	f	4.33		4.42	—	—	—	
D	f	3.88		3.90	—	—	—	
D	m	3.48	3.49Å	3.47	—	—	—	
M		—	—	—	(3.411)Å	(3.411)Å	(3.411)Å	s
D	f	3.25	3.25		—			
D	m	(2.918)	(2.918)	(2.918)	2.93	—	—	
M		—	—	—		2.88	2.88	f
D, M	ff		2.68	2.70	2.70	2.70	2.72	f
M		—	—	—	2.53	2.53	2.54	m
M		—	—	—	—	2.29	2.28	f
D, M	m	2.20	2.21	2.21	(2.197)	(2.197)	(2.197)	m
M		—	—	—	—	2.11	2.12	f
D	s	(2.089)	(2.089)	(2.089)	2.08	—	—	
D	f	1.93	1.93	1.92	1.93	—	—	
M		—	—	—	—	1.88		ff
M		—	—	—	1.82	1.83		ff
M		—	—	—	1.70	1.70	1.70	m
D	ff		1.67		—	—	—	
D	ff		1.62		—	—	—	
M		—	—	—	1.60	1.59	1.59	f
D	f	1.55	1.54	1.54	—	—	—	
M		—	—	—	(1.518)	(1.518)	(1.518)	m
D	s	(1.460)	(1.460)	(1.460)	1.46			
M		—	—	—	1.42	1.43	1.43	f
D, M	m	1.34	1.34	1.34	1.34	1.33	1.33	m
D	f	1.29	1.29	1.30	—	—	—	
M		—	—	—	1.26	(1.260)	(1.260)	m

Note: In the first column of this table D and M refer to dumortierite and to mullite respectively. The patterns of dumortierite decomposed at 1200° and at 1500° are practically those of mullite;[11] the spacings of the principal lines of dumortierite are given in Table 3. Absences of reflections are indicated by bars; vacancies (as for instance for the long spacing lines in the 1100° column) do not mean the absence of these lines. Standard lines are enclosed in parentheses.

[11] J. T. NORTON. Journ. Amer. Cer. Soc. **8**: 401 (1925); L. NAVIAS and W. P. DAVEY, Journ. Amer. Cer. Soc. **8**: 640 (1925); R. W. G. WYCKOFF, J. W. GREIG and N. L. BOWEN, Amer. Journ. Sci. (in press).

The pattern of this mineral heated at 1150° is to be interpreted as that of dumortierite with a small amount of admixed mullite; the photograph arising from the 1150–80° heating shows mainly mullite with some undecomposed dumortierite. The patterns of these high temperature products are somewhat weaker than those of unchanged

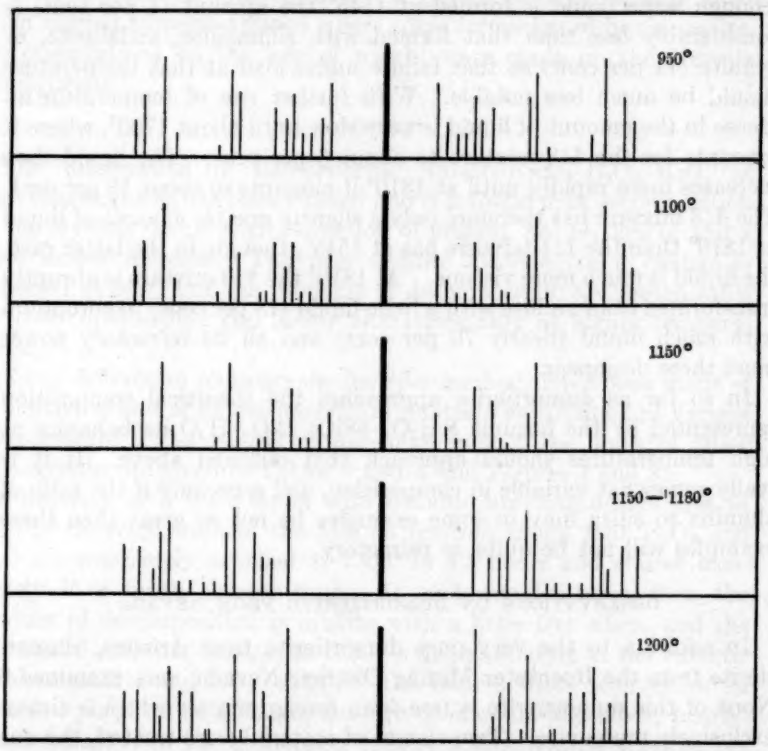


Fig. 3.—Tracings showing the positions and the approximate relative intensities of the principal lines observed in the powder photographs of dumortierite heated at various temperatures.

dumortierite, but they do not show the intense blackening which should be found if any considerable portion of the sample had become amorphous.

DUMORTIERITE AS A REFRACTORY

Dumortierite is to be regarded favorably as a basis for refractory bodies, and, on account of its higher Al_2O_3 content, as having some

advantages over the silicates of composition $Al_2O_3 \cdot SiO_2$, namely, sillimanite, andalusite, and cyanite. Indeed, dumortierite may, for refractory purposes, be looked upon as having the formula which was, by mistake, originally assigned to it, namely, $4Al_2O_3 \cdot 3SiO_2$, and its thermal behavior may be read off from the alumina-silica diagram. Though some liquid is formed at 1545° the amount (4 per cent) is considerably less than that formed with sillimanite, andalusite, or cyanite (14 per cent) so that failure under load at that temperature should be much less notable. With further rise of temperature increase in the amount of liquid is very slow until about 1700°, where it amounts for the 4:3 mixture to about 6 per cent. The liquid then increases more rapidly until at 1810° it amounts to about 18 per cent. The 4:3 mixture has therefore only a slightly greater amount of liquid at 1810° than the 1:1 mixture has at 1545°, though, in the latter case, the liquid is much more viscous. At 1810° the 4:3 mixture is abruptly transformed from mullite with a little liquid (18 per cent) to corundum with much liquid (nearly 70 per cent) and all its refractory power must there disappear.

In so far as dumortierite approaches the theortical composition represented by the formula $8Al_2O_3 \cdot 6SiO_2 \cdot B_2O_3 \cdot H_2O$ its behavior at high temperatures should approach that outlined above. If it is really somewhat variable in composition, and especially if the ratio of alumina to silica may in some examples be not so great then these examples will not be quite so refractory.

OBSERVATIONS ON DUMORTIERITE FROM NEVADA

In addition to the very pure dumortierite from Arizona, dumortierite from the Rochester Mining District, Nevada, was examined.[12] None of this dumortierite is free from foreign matter which is almost exclusively muscovite. Two classes of material were treated, the one a select specimen with 3 or 4 per cent muscovite, the other, with about 20 per cent muscovite, which appears to represent the general run of material there available. At lower temperatures decomposition of the dumortierite into mullite and silica takes place in exactly the same way as in the Arizona mineral. Even at high temperatures the specimen with only a little mica did not show any significant departure in behavior from the purer Arizona mineral. In the specimen with the greater amount of mica, however, definite sintering begins at a lower

[12] This material was kindly supplied by ERNEST E. FAIRBANKS, Bureau of Mines Reno, Nevada.

temperature. The formation of some liquid is in fact apparent at 1500°, and at 1550° the amount of liquid is definitely greater than that in the specimen with only a little mica. Both give a pure white product even when definite partial melting has occurred. In this respect the pale-colored dumortierite from Nevada differs from the deep-blue Arizona mineral which, as we have seen, gives a slightly colored product when carried to temperatures where some formation of liquid occurs. No observations on the loss of weight were made on the Nevada dumortierite.

SUMMARY

The dissociation of dumortierite, $8Al_2O_3 \cdot 6SiO_2 \cdot B_2O_3 \cdot H_2O$, at high temperatures has been studied and it is found that decomposition of the crystals occurs with formation of mullite, $3Al_2O_3 \cdot 2SiO_2$, and a little excess material. The first definite evidence of a change is obtained at 950°, but the products of decomposition are recognizable by their microscopic and X-ray characters only at higher temperatures.

X-ray diffraction photographs (powder method) have been made of dumortierite and of its decomposition products as obtained at various temperatures. The results of measurements of the lines of these photographs are given in Tables 3 and 4 and Figures 2 and 3.

Formation of a little liquid with definite sintering occurs first at 1550°. Determination of the loss on ignition shows that B_2O_3 and H_2O are completely expelled at 1500° in 4.5 hours and almost completely in a much shorter time. At such temperatures, then, the product of decomposition is mullite with a little free silica, and the fact that liquid first appears at 1550° is due to melting at the eutectic between mullite and SiO_2 (1545°). The mineral thus behaves for all practical purposes as a simple mixture of alumina and silica, nearly, if not actually, in the proportion $4Al_2O_3 \cdot 3SiO_2$, and its thermal behavior can be read off directly from the alumina-silica diagram, Fig. 1.

ENTOMOLOGY.—*The occurrence of* Phlebotomus *in Panama.*[1] RAYMOND C. SHANNON, Bureau of Entomology. (Communicated by S. A. ROHWER.)

The members of the genus *Phlebotomus* form one of the best known groups (*Psychodidae*) of bloodsucking Diptera. Particularly is this true in certain southern European, Asiatic, and African countries where, owing to the fact that certain species are carriers of disease and others are suspected to be, a rather thorough investigation has been made of their habits, distribution, and classification.

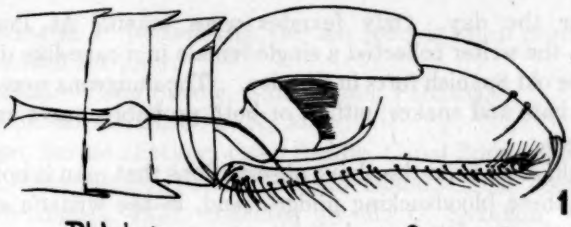
The American species have yet to undergo such an intensive investigation, for only twelve have been described, and these mostly from South America. Several species have been suspected of carrying disease, there being considerable evidence to show that *P. verrucarum* Townsend is the vector of verruga fever in Peru, while both *P. brumpti* and *P. intermedius* are suspected of being transmitters of American leishmaniasis.

There are as yet no published records of the occurrence of *Phlebotomus* in Panama. However, in 1911, Mr. August Busck collected two females at Cabima, Panama. These were tentatively determined by Knab as "*P. squamiventris* L. & N." and "*U. rostrans* Summers," respectively.

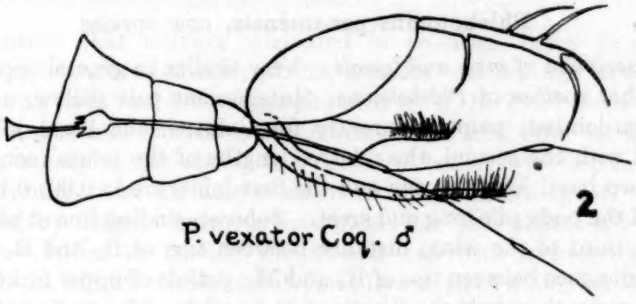
In 1923, the writer collected a number of specimens, at three localities in Panama. The first were taken in the month of May in the daytime by means of sweeping with a net at the bases of large coipu trees growing in the midst of an uncut forest area located near Cano Saddle, on one of the back arms of Gatun Lake. A number of females and one male were secured in this manner. In June and July, while the writer was investigating the mosquito fauna of Barro Colorado Island, in Gatun Lake, at that time a wholly uninhabited and nearly virgin forest area, he again encountered *Phlebotomus*. The midges were attracted by the camp light (a gasoline lantern) and rested upon objects well within the range of the light. They bit rather frequently, the bite being distinctly sharper than an ordinary mosquito bite. Towards morning they would leave the light and hide themselves

[1] An excellent summary of our knowledge of the species of *Phlébotomus* has been published by F. LARROUSSE, *Etude Systematique et Médicale des Phlébotomes*, 1921, pp. 1–106.

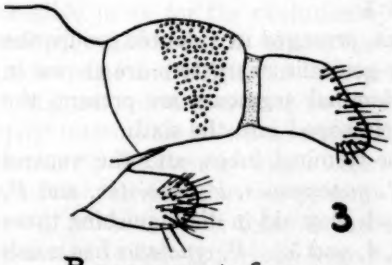
Fig. 1.—Male terminalia of *Phlebotomus panamensis* Snn. Fig. 2.—Male terminalia of *P. vexator* Coq. Fig. 3.—Female terminalia of *P. panamensis* Snn. Fig. 4.—Female terminalia of *P. vexator* Coq. Fig. 5.—Female terminalia of *P. cruciatus* Coq.



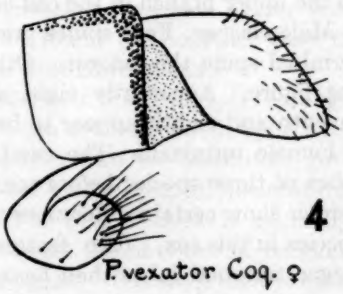
Phlebotomus panamensis Snn. ♂



P. vexator Coq. ♂



P. panamensis Snn. ♀



P. vexator Coq. ♀

P. cruciatus Coq. ♀

Figs. 1, 2, 3, 4, and 5; see page 190 for description

away for the day. Only females were taken. At Porto Bello, Panama, the writer collected a single female in a cave-like dungeon in one of the old Spanish forts in the city. The dungeons were inhabited both by bats and snakes; either, or both probably, serve as hosts for the midges.

It would seem from the above observations that man is not a normal host for these bloodsucking midges; and, in the writer's experience, no ill effects were felt from their bite.

All of the collections of *Phlebotomus* from Panama proved to belong to a single new species, which is here described.

Phlebotomus panamensis, new species

Description of male and female.—Very similar in general appearance to other species of *Phlebotomus*. Integument pale yellow; antennae sixteen-jointed; palpi apparently four-jointed, the basal joint well fused with the second, the relative lengths of the joints (considering the two basal joints as one and the first joint) are 1: 0.90: 0.15: 0.25. All of the body pile long and erect. Subcosta ending free at about the basal third of the wing; distance between tips of R_1 and R_2 greater than distance between tips of R_2 and M_1; petiole of upper forked cell a little more than half the length of R_2; petiole of lower forked cell is to the upper branch of the cell as 3:5.

Male clasper: Four spines present, arranged in a double group; the terminal spine the longest. Other genitalic characters are shown in the figure. Apparently eight abdominal segments are present, the seventh and eighth appear to be telescoped into the sixth.

Female terminalia: The cerci, or terminal lobes, and the ventral lobes of three species before me, *P. panamensis*, *P. cruciatus*, and *P. vexator* show certain differences which may aid in distinguishing these species in this sex. (See figures 3, 4, and 5.) *P. cruciatus* has much larger terminal lobes than have the other two species, and they are more than twice as long as broad and more finely setulose; in *P. panamensis* the terminal lobes are subquadrate, except that the lower distal corner is obtusely produced; in *P. vexator* the terminal lobes are similar to those of *P. panamensis*, except that they are somewhat larger.

The key to the American species, based on male genitalia, given by Larrouse, shows that *P. longipalpis* Lutz & Neiva (Brazil) may be the nearest ally, among the known species, to *P. panamensis*. The terminal palpal joint in that species is longer than any of the preceding

joints, whereas in *P. panamensis*, the last joint is much shorter than the antepenultimate joint.

Type locality.—Cano Saddle, Canal Zone, Panama.

Type.—Cat. no. 28726, U. S. N. M.

Male type, female allotype, Cano Saddle, Canal Zone; eight female paratypes, Cano Saddle, Barro Colorado Island, Canal Zone, Porto Bello, May–August, 1923, collected by R. C. Shannon; Cabima, Panama, May 22, 1911, collected by A. Busck.

ANTHROPOLOGY.—*The subjective element in magic.* JOHN R. SWANTON, Smithsonian Institution.[1]

The theory that religion originated in animism, belief in souls resident in or associated with plants, animals, natural and artificial objects, was, as is well known, propounded by E. B. Tylor more than fifty years ago; and, as is also well known, J. G. Frazer later set up an opposing theory to the effect that animistic beliefs were secondary, having sprung from an earlier stage in which men's minds were dominated by magic. Frazer's hypothesis has been repeatedly and thoroughly grilled by leading British and American anthropologists such as Lang, Marett, Goldenweiser, and Lowie, all of whom take issue with the learned author, and in general it may be said that there is no tangible proof for the evolutionary succession for which Frazer contended. However, his critics have not found it altogether easy to place magic and religion in their proper mutual relations.

Magical practices seem to be accomplished in three ways, (1) through spirit intermediaries whose coöperation can not be counted upon with certainty, (2) through spirit intermediaries who are absolutely governed by the magician—or perhaps rather by the magical incantation, or (3) without spirit intermediaries. The first of these is generally conceded to belong in very large measure in the province of religion, while the second is usually classed as magical. But since the theoretical control over spirits exercised by a worker in magic varies greatly it is difficult to draw a sharp line between practices belonging to these two classes. The conception of spirit helpers is certainly furnished by religion, and where their services are absolutely constrained we may perhaps say that we have a magic-religion complex with magic dominant.

Practices of the third type are, of course, those most typical of magic as distinguished from religion, but when we come to concrete

[1] Received February 19, 1926.

examples the anthropomorphizing urge is so great that it is difficult to be sure that they are entirely sterilized of the religious element. And, having apparently segregated cases of true magic, are we sure that what we have left is anything more than the effect of a theory of causation differing in no respect from hypotheses involving purely natural phenomena? Indeed primitive man frequently applies terms generally reserved for the supernatural to purely natural occurrences. There are people with little or no superstition in their make up who believe that mind may communicate with mind directly over wide spaces. If it should turn out that they are right, the primitive magician who attempts to benefit or injure at a distance by mental action would deserve so much the more credit. Should we *then* class his efforts as magical or scientific? But that is not all. Granted that they are magical and supernormal from our point of view, are they from his? Lowie well says: "But the residue [of native lore], which *we* are obliged to reject when testing it in the light of *our* knowledge, does not, for that reason, belong to a different category from a psychological point of view. . . . . In so far as [primitive man] observes and reasons without enveloping his mental operations with the atmosphere of supernaturalism he is none the less a scientist or at least a precursor of science because of his errors, for mistakes from sheer ignorance are committed by our greatest thinkers."[2] Not only so, but some of our greatest thinkers, Kepler for instance, hit upon cardinal scientific truths while their minds were enveloped in "the atmosphere of supernaturalism" and therefore the atmosphere of supernaturalism becomes a rather insecure determinant of the distinction between magic and science.

But whether or not any of the scientific attitude attaches to magical practices and superstitions of related character numbers of them perform subjective services, or supposed services, of another kind which go far toward explaining their existence and their persistence. I mean simply this, that the act in question keeps a desired end in view, or at least serves to exclude from the thoughts an undesired and hence unpleasant end. When, for instance, the Zulu chews a bit of wood "in order, by this symbolic act, to soften the heart of the man he wants to buy oxen from, or of the woman he wants for his wife,"[3] the proceeding at least suggests and keeps before his mind the accomplishment of something agreeable. In view of the unexplored character of

[2] R. H. Lowie, *Primitive Religion*, p. 148.
[3] E. B. Tylor, *Primitive Culture*, 1: 118 (quoted from Grout, Zulu-land).

much of the mental life even a civilized man might, under similar circumstances, think that *perhaps* his rite would be of some avail, and in the grade of development to which the Zulu belongs such a suggestion would be tenfold more powerful. At least, if timidity, remoteness from the persons in question, or other causes prevented the performer from taking more effective action, such a bit of imitative magic would furnish an outlet for his unsatisfied mental strivings.

Similarly, when the wizard endeavors to injure or kill an enemy by making an image of him and mistreating it in various ways, his efforts will ordinarily be without direct avail. Still, the desired end may be accomplished by the effect of these activities on the equally superstitious mind of his victim, and in any case the act serves to feed the spirit of hatred which the magician entertains, helps him to "nurse his wrath," and thus performs a service, although a perverted one, to the doer. The same argument applies in the case of hunting charms, war medicines, mascots, etc. They suggest success, help to keep up the spirit of the owner or owners, and hence actually add to their courage and feeling of competency. Even the possession of a rabbit's foot may have an exhilarating effect on a highly educated gentleman of our own times which he would be ashamed to admit. Faced with an uncertain future of infinite possibilities, and recognizing that unknown laws are at work about him, the bewildered individual tends to grasp at anything which suggests a happy outcome and, at least, something associated in his mind with success. This may be a thing purely individual, as in the wearing of a particular scarf-pin, or a certain dress, or the carrying of a sketch as in instances cited by Tozzer,[4] or it may be something which his group or associates have come to hold in such esteem. Cases of the latter kind are the rabbit's foot just mentioned, the mascot of the college or the athletic team, or the palladium of a tribe. When in doubt or perplexity, man tends to lean on his fellows or his group, and when the group has come to associate good or ill fortune with this, that, or the other object, it is the easiest thing in the world to resolve the perplexity by accepting the group superstition. This, of course, applies to group ideas of all kinds, whether or not of the nature of charms. "Of course," we say, "*we* are not superstitious," but we do not know how to meet the present emergency, the use of a rabbit's foot or a particular amulet is an ancient and widely spread custom, and that fact argues that "there must be something in it," and anyhow "it can do no harm."

[4] A. M. Tozzer, *Social Origins and Social Continuities*, pp. 242–266. 1925.

A personal experience may help along the thought at this point. When a boy the writer used to dress in a room heated by an airtight stove. Before brushing his hair he was in the habit of wetting the hairbrush at the washstand, and as this was on the opposite side of the room from the mirror, he was obliged to pass the stove going and coming. As he passed the stove on his way back he fell into the habit of flirting a little water off of his brush upon it in order to hear the sizzle. But, after this little custom had been kept up for some time, he one day determined he would omit the ceremony, and he was straightway conscious of a distinct sense of discomfort, while the thought flashed through his mind from nowhere in particular, "Supposing bad luck should follow the omission." Evidently the cause of the discomfort was the breaking of a partially established habit, a discomfort of the kind that compelled old Dr. Johnson to go back and strike any fence post he had omitted hitting with his cane. The thought consequent on the discomfort may have had a religious origin; it was perhaps a vague attempt to interpret in religious terms an unpleasant sensation which was purely psychological, the distaste of the organism toward any interference in a customary exercise.

In most cases such superstitions probably do "do harm," because life is too short to clutter it up with useless formulas. The mental machinery will register impressions based on sound reasoning as readily as meaningless imitations of what our neighbors do or our ancestors have done, and our time should be devoted to the former occupation.

However, there are suggestions connected directly with magic which are beneficial, even though they may be irrational. There is no question that certain sights and sounds have an alleviating effect on the sick. Some perhaps serve merely as counter irritants to remove the mind from its immediate troubles, but others are of a kind to turn the flow of the patient's thoughts strongly to a happy outcome. When a Haida woman was about to give birth, it was customary to let an eel slide down to her feet inside of her clothing, the slippery nature of the creature and the direction it took indicting easy parturition, and a similar suggestion was involved in many magical practices on this and other occasions. If a patient strongly believed that the pain in his arm was due to a witch arrow and the doctor could seem to suck this out and actually show it to him, the alleviation of the apparent symptoms was probable and their actual alleviation in certain cases more than likely.

The Chickasaw attempted to cure by a powerful use of group suggestion. The entire neighborhood would be summoned to the house of the sick person, a fire lighted east of the main doorway, which was always toward that quarter as being the good luck direction, little canes adorned with ribbons, images, and other objects properly conjured by the doctor, were stuck in the ground near the fire, and all of the guests danced about between the fire and the house while the sick man himself sat in the doorway looking on, or was supported by others in that position. The vigorous actions of the dancers were supposed to energize the patient and "dance away" his malady. In other words he was made the focus of a powerful assembly of suggestions, composed of all kinds of good luck signs, the concentrated belief of his neighbors, and their display of energy which he was taught to think was working upon his indisposition.

The elaboration of the charm, mascot, fetish, palladium, or ceremonial in order to suggest more intensely the end to which it was believed to lead would of course be thought to increase the possibility of attainment, *but* it would certainly make the desire more vivid and in the same measure increase the subjective satisfaction of the magician and his friends. Hence such efforts cannot be said to have been entirely unserviceable although in many cases they were socially undesirable. It is perhaps worth considering whether this motive may not have acted as a powerful stimulus in the evolution of the arts.

My conclusion is that, whatever religious element may attach to magic, it is to be explained mainly by reference to immediate psychological processes, particularly those of the magician himself.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY

929TH MEETING

The 929th meeting, the first of the year 1926, was held in the Cosmos Club auditorium on Saturday evening, January 9, 1926. The meeting was called to order at 8:31 by President BOWIE with 67 persons present. The address of the evening was given by the retiring president, J. A. FLEMING, on *The magnetic and electric survey of the earth; its physical and cosmical bearings and development.* It appears in full in an early issue of the JOURNAL. (This JOURNAL, **16**: 109–132, 1926.)

930TH MEETING

The 930th meeting was held in the auditorium of the Cosmos Club on Saturday evening, January 23, 1926. The meeting was called to order by President BOWIE at 8:15 with 49 persons in attendance.

Program: E. O. HULBURT: *The propagation of radio waves over the earth.* —In this paper a quantitative theory of the propagation of radio waves over the earth is presented. Larmor's theory of refraction due to the electrons of the Kennelly-Heaviside layer does not explain the "skip distances" for short radio waves (regions of silence around the transmitter which Taylor's measurements showed to be 175, 400, 700, and 1300 miles in radius in the daytime, averaged over the year, for waves of 40, 32, 21 and 16 meters, respectively, and which are surrounded by zones of strong signals). The range as a function of wave-length shows a minimum for about 200 meters which suggests the introduction of a critical frequency term. If the effect of the magnetic field of the earth on the motion of the electrons is taken into account, as suggested by Appleton and by Nichols and Schelleng, the modification of the Larmor theory necessary to fit it to the experimental facts is secured.

The upper atmosphere is assumed to contain N free electrons per cubic centimeter, and neglecting absorption the dispersion equations are worked out for various modes of polarization of the radio waves. Then the skip distances are computed, making various assumptions as to the electron density distribution. (a) Reflection theory. As a first approximation the layer is taken to be sharply separated from the un-ionized lower atmosphere. At this layer total reflection occurs in accordance with Snell's law. (b) Refraction theory. The following distributions are considered: (1) Density increasing linearly with the height h, beginning at a certain height h_0; (2) Density proportional to h^2; (3) Density proportional to e^h; (4) Density proportional to $h^{1/2}$. Comparison with the experimental skip distances shows good agreement, and indicates that the radio waves which just reach the edge of the zone beyond are refracted around a curved path, reaching in the daytime a maximum height of from 97 miles (case 1, $h_0 = 21$ miles, and case 2) to 149 miles (case 3). At this height the electron density comes out close to 10^5 electrons per cubic centimeter. At night the electron density gradient is less and the height is greater.

These conclusions agree with physical conceptions from other evidence. From the dispersion equations it follows that for waves of 60 to 200 meters, total reflection may occur from the electron layers at all angles of incidence. From this result, combined with interference between various modes of polarization of the radio rays, a detailed qualitative explanation of many fading phenomena is presented. Further conclusions are: That the ions in the atmosphere have little effect in comparison with the electrons; that for longer waves the Larmor theory is correct; that short waves are propagated long distances by refraction in the upper atmosphere and reflection at the surface of the earth, not by earth-bound waves; that waves below 14 meters can not be efficiently used for long distance terrestrial communication, but appear to offer a possibility of interplanetary communication. (*Author's abstract.*)

J. H. SERVICE: *Recent results with radio-acoustic ranging.* (Illustrated with lantern slides.) The radio-acoustic method of position finding was taken up by the Coast and Geodetic Survey in the fall of 1923. The introduction to the paper reviews briefly the construction and operation of the original apparatus and the procedure originally followed, involving stopping the ship, firing a bomb in the water alongside and recording the time. Sound energy from the bomb travels through the water to hydrophones at two or more shore stations. The reception of sound at a given shore station, by means of amplifier and relays, causes a characteristic radio signal to be sent

out from that station, which is received aboard the ship and timed. Time of travel of sound energy and thence distance to each station is thus obtained.

The following improvements have been made during the past two years: Design of a special bomb for great distances, more efficient procedure in hydrophone and cable installation and recovery, the obtaining of fixes without reduction of the speed of the survey ship, elimination of stray hydrophone disturbances, automatic shore station operation and improved methods of plotting.

The method has been shown to be practical for distances between ship and shore station up to 200 miles (unless unfavorable bottom conditions intervene), and gives a location for the ship with a maximum distance error varying from some 75 meters to somewhat less than a mile as the distance between ship and shore stations increases from 10 miles to 200 miles. A shore station will function automatically for over a week of continuous operation without attention.

Some of the problems awaiting solution are: obtaining a more suitable hydrophone cable, the modification of the apparatus to permit the use for short distances of a sound source more convenient than explosions, the development of a sound receiver better than a microphone, and modification of the apparatus so as to make possible the detection of sound energy transmitted across unfavorable bottom conditions.

The use of the method has brought to light strong evidence to indicate that the sound energy from bomb to hydrophone is transmitted largely by means of multiple reflections between the surface and the bottom. (*Author's abstract.*)

H. A. MARMER, *Recording Secretary.*

SCIENTIFIC NOTES AND NEWS

The annual party of the Pick and Hammer Club was held on March 6. Among the former members of the U. S. Geological Survey present were: RALPH ARNOLD, petroleum engineer of Pasadena, California; EDWARD SAMPSON of Princeton University; and K. C. HEALD.

Mrs. NORA DOWELL STEARNS resigned from the Water Resources Branch of the U. S. Geological Survey on March 1.

The following members of the U. S. Geological Survey expect to attend the International Geological Congress in Madrid, Spain, May 24–31: H. G. FERGUSON, M. I. GOLDMAN, G. M. HALL, D. F. HEWETT, and E. O. ULRICH. Mrs. Ferguson, Mrs. Goldman, and Mrs. Hewett will also be members of the party. Most of the geologists will attend one or more of the geological excursions to regions of especial interest in Spain and northern Africa. Mr. HEWETT left Washington March 12, and will make several geologic investigations in Greece, Italy, and Sardinia before the congress. Mr. GOLDMAN leaves on April 15, Mr. FERGUSON April 24, and Mr. ULRICH May 12.

ARTHUR KEITH is on leave from the U. S. Geological Survey for the two months beginning March 17, to give a course of lectures on *Structural geology of North America* at the University of Texas, at Austin.

ROBERT T. BOOTH will be succeeded April 1, 1926, by RICHARD H. GODDARD as observer-in-charge of the Huancayo Magnetic Observatory (Peru) of the

Carnegie Institution of Washington. Mr. Booth will return to Washington across South America via the Amazon as a member of the special expedition of Messrs. DAHL and RAMBERG.

DAVID WHITE, W. C. MENDENHALL, W. T. THOM, Jr., L. W. STEPHENSON, H. D. MISER, C. H. DANE, H. W. HOOTS, N. W. BASS, and J. D. NORTHOP of the United States Geological Survey attended the annual meeting of the Petroleum Geologists at Dallas, Texas, on March 25, 26, and 27.